Technical Memorandum

Background Uranium Concentration

Homestake Millsite, Grants New Mexico

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Prepared for: Bluewater Valley Downstream Alliance and Multicultural Alliance for a Safe Environment

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SUMMARY

The purpose of this technical memorandum is to propose defensible background concentrations for uranium (U) for the primary aquifers at the Homestake Millsite in Grants NM. A background concentration is the concentration that occurred in the aquifers prior to mining and milling in the area. The primary source is the large tailings pile (LTP) created at the Grants mill. I used historic concentration data from a Homestake Mining Company data to estimate background, which was based on data that occurred prior to impacts from mining and milling. Data subject to trends or to concentration spikes were not used because this is evidence of impacts. Concentrations that have returned to much lower levels after high spikes may be considered background if the spikes could be linked to temporary leakage.

A reasonable background value for U in the alluvium is 0.04 mg/l based on 1995 through 2004 data for the unaffected near-upgradient wells and evidence that further upgradient wells demonstrate the effects of advection from upstream sources. Well DD, which is in a separate section of the aquifer which has high U concentrations, was not utilized for setting background. Substantial non-detect data from 1976 in alluvial wells south of the LTP support setting background U no higher to 0.04 mg/l, but it could be much lower because the higher values in the alluvium south of the LTP could be millsite related.

In the Upper Chinle non-mixing zone, most wells used by HMC to estimate background have been affected by millsite leakage, as demonstrated by the upward trend in the concentrations. U concentration data for wells CW3 and 931 prior to 1987, which are apart from the East Fault and the subcrop, are the exception. Also, mixing zone data from Felice Acres in the 1970s provides evidence for setting low background concentrations. A reasonable background for the Upper Chinle non-mixing zone is 0.03 mg/l based on data preceding 1987 at CW3 and 931.

The Middle Chinle subcrops beneath an area of alluvium near well DD that had high U concentrations beginning early in the 1980s. HMC included concentration data clearly impacted by millsite leakage, including that from wells CW1 and CW2 and five anomalous data points at CW28. A fair background level for the nonmixing zone Middle Chinle aquifer would be 0.04 mg/l, based on frequency analysis of HMC's Middle Chinle well data from 1982 through 2002 excepting wells and observations described above. It also accounts for the many Middle Chinle wells with very low concentrations early in the period by using a lower estimate even though the data is not amenable to being added to the frequency analysis. Using this data accounts for the fact that U concentrations are variable, but most were initially very low.

There were very high U concentrations in the Middle Chinle nonmixing zone and the alluvium within the Felice Acres subdivision beginning the late 1970s. There are two possible explanations for the high U concentrations, seepage through a fracture into the Middle Chinle somewhere north near the LTP or a spill in the alluvium reaching the Middle Chinle. There is no data or documentation to support either hypothesis. The subdivision is north of the Middle Chinle mixing zone which means there is a layer of Chinle formation between the contaminated alluvium and Middle Chinle that is not considered conducive to flow. If the alluvium is the source, the only possible pathway to the Middle Chinle would be through an unidentified fracture. That the concentrations are much higher in the Middle Chinle than in the alluvium and the locations are not near the mixing zone makes seepage from the alluvium an unlikely source.

Contamination has reached the Lower Chinle since 2002, but it is clearly anthropogenic. HMC's recommended 0.03 mg/l background is appropriate for the Lower Chinle nonmixing zone.

HMC grossly overestimated the background concentrations for the Chinle mixing zones. Concentrations in the Middle Chinle mixing zone are very high due to seepage from the west part of the alluvial aquifer. HMC used combined data from 1987 through 2003 to estimate background equal to 0.18 mg/l. With most U concentrations in the Upper and Lower Chinle mixing zones being less than 0.05 mg/l, the high values Middle Chinle mixing zone controls HMC's estimated background. For background determination, all data from the Upper and Lower Chinle mixing zone and Middle Chinle well CW15 is appropriate to consider for background. The 95% exceedance is 0.048 mg/l, with the median being 0.0275 mg/l. A fair background level for the Chinle mixing zones is 0.05 mg/l, not the 0.18 mg/l as proposed by HMC. A higher background concentration in the Chinle mixing zones than in the alluvium is appropriate because the water could contain U passing into the Chinle.

The following table summarizes proposed background U concentrations and provides the basis for the recommendation. The text below provides a detailed description of the estimate.

Aquifer	HMC Background (mg/l)	Proposed Background (mg/l)	Basis for recommendations
Alluvial	0.16	0.04	Statistics from the near upgradient wells, not including well DD, from 1995 through 2004, manually adjusted by the understanding that many wells in the far upgradient well field and in wells southwest of the LTP have much lower U concentrations.
Upper Chinle	0.09	0.03	A reasonable background for the Upper Chinle non-mixing zone is 0.03 mg/l based on data from before 7/22/87 at CW3 and 931. All other wells have been affected by LTP seepage during the period for which concentrations are available.
Middle Chinle	0.07	0.04	Background based on frequency analysis of HMC's Middle Chinle well data from 1982 through 2002 excepting wells and observations described in the text. Recommended background accounts for the many Middle Chinle wells throughout the area with very low concentrations early in the period by using a lower estimate even though the data is not amenable to being added to the frequency analysis. U concentrations varied, but most were initially very low.
Lower Chinle	0.03	0.03	Almost all data prior to 6/26/2002 is less that 0.03 mg/l
Chinle Mixing Zone	0.18	0.05	Based on the 95% exceedance for the Upper and Lower Chinle and well CW15 from the Middle Chinle, with data from 1987 through 2018. LTP seepage has affected much of the data used by HMC in the Middle Chinle, as described in the text.

INTRODUCTION

This technical memorandum uses an understanding of the conceptual flow model and the database of groundwater chemistry data provided by Homestake Mining to estimate alternative background uranium (U) concentrations for the alluvial, Upper Chinle nonmixing, Middle Chinle nonmixing, Lower Chinle nonmixing, and Chinle mixing zone. The proposed background concentrations provide an alternative to those previously proposed by Homestake (NRC 2006) and reviewed by Ulrich et al (2019). The proposed background is based on an improved understanding of the flow paths.

Work by Ulrich et al (2019) either verified the 2006 estimated background or increased the values, based on new statistical procedures. The authors used data provided to them by ERG that had been used to make the 2006 estimates. They simply performed new statistical analysis and did not reassess whether the data used was appropriate for determining background. Neither study defined background, but HMC (2015) describes it as being the water quality that existed prior to milling:

> The groundwater flow regime that existed prior to the milling activities at the [Grants Restoration Project] is evaluated based on available historical records. The present groundwater flow and quality conditions are also discussed, with particular emphasis on the up-gradient background conditions. Following completion of groundwater restoration at the GRP, the groundwater regime is expected to ultimately revert to a condition similar to that of the pre-milling condition. (HMC 2015, p 1-1)

Background is ostensibly the condition that existed before milling began but the statistical analysis uses data collected since milling began. The agency and industry analyses do not realistically attempt to find well data that has not been impacted by industry. Simply applying a statistical analysis to a body of data does not provide an accurate background estimate if milling has affected part of the data.

The technical memorandum uses Myers conceptual flow model (Myers 2015), HMC (2015) and figures and concepts presented by Mark Purcell on September 12, 2019[1] to describe the U transport concepts. It then uses the HMC database to consider the estimated background concentrations. Specifically, I consider data from the same wells used by NRC (2006) but also consider data outside of HMC's period and do not use data obviously affected by milling. Earlier data may better represent the background and later data if it has decreased from impacted levels may represent the chemistry possible once anthropogenic impacts cease. Additionally, I consider wells with U concentrations from before 1982 not considered by HMC to support or refute background concentrations hypotheses. The focus is on U concentrations.

CONCEPTUAL SITE FLOW MODEL

Groundwater flow occurs in four aquifers at the Homestake Millsite. Alluvium is on the surface and is generally saturated near and beneath the LTP (Figure 1). The Chinle formation is a sandstone shale formation underlying the alluvium throughout the site. It has three water-bearing zones, the Upper, Middle and Lower Chinle aquifers. The Upper and Middle Chinle aquifer are sandstone and the Lower Chinle aquifer is fracture shale. Each zone subcrops under the alluvium, so alluvial water can flow into each Chinle zone, depending on water levels in each zone (Figure 1).

The Upper Chinle subcrops mostly between the East and West Fault including under the western half of the LTP. The subcrop is near an apparent Middle Fault which also lies under the LTP (Figure 2). The flow direction is generally north to south. The Middle Chine subcrops west of the West Fault west of the LTP and south of Broadview Acres. Flow is north to south west of the West Fault and south to north in between the faults and east of the East Fault (HMC 2015). The Lower Chinle aquifer subcrops further west and south. Acres Flow in the Lower Chinle is southwest from the outcrops to the northeast. The Chinle formations generally dip west to east across the site, although in three dimensions with faulting it can be complicated (Figure 3).

The general flow direction in the alluvium is north to south with some conceptual flow pathways shown in Figure 4. Alluvial groundwater flow originates in the north and was affected by uranium mining and milling beginning in the 1950s (Myers 2015). The U in that water has affected groundwater quality in the aquifers near the LTP. As will be discussed below, high U concentrations occur in an alluvial water

[1] Homestake Mining Company NPL Site Back Study, EPA/NM/BVDA/MASE Meeting September 12 2019, presentation by Mark Purcell. Referred to as "Background Presentation" herein.

flow path on the west side of the aquifer, which generally coincides with shallower depth to bedrock (Figure 4). A larger alluvial channel passes beneath the west side of the LTP and prior to the millsite passes low-U groundwater. The deep alluvial channel generally coincides with the Upper Chinle subcrop and the shallow, high-U alluvial channel generally coincides with the Middle Chinle subcrop (Figure 5).

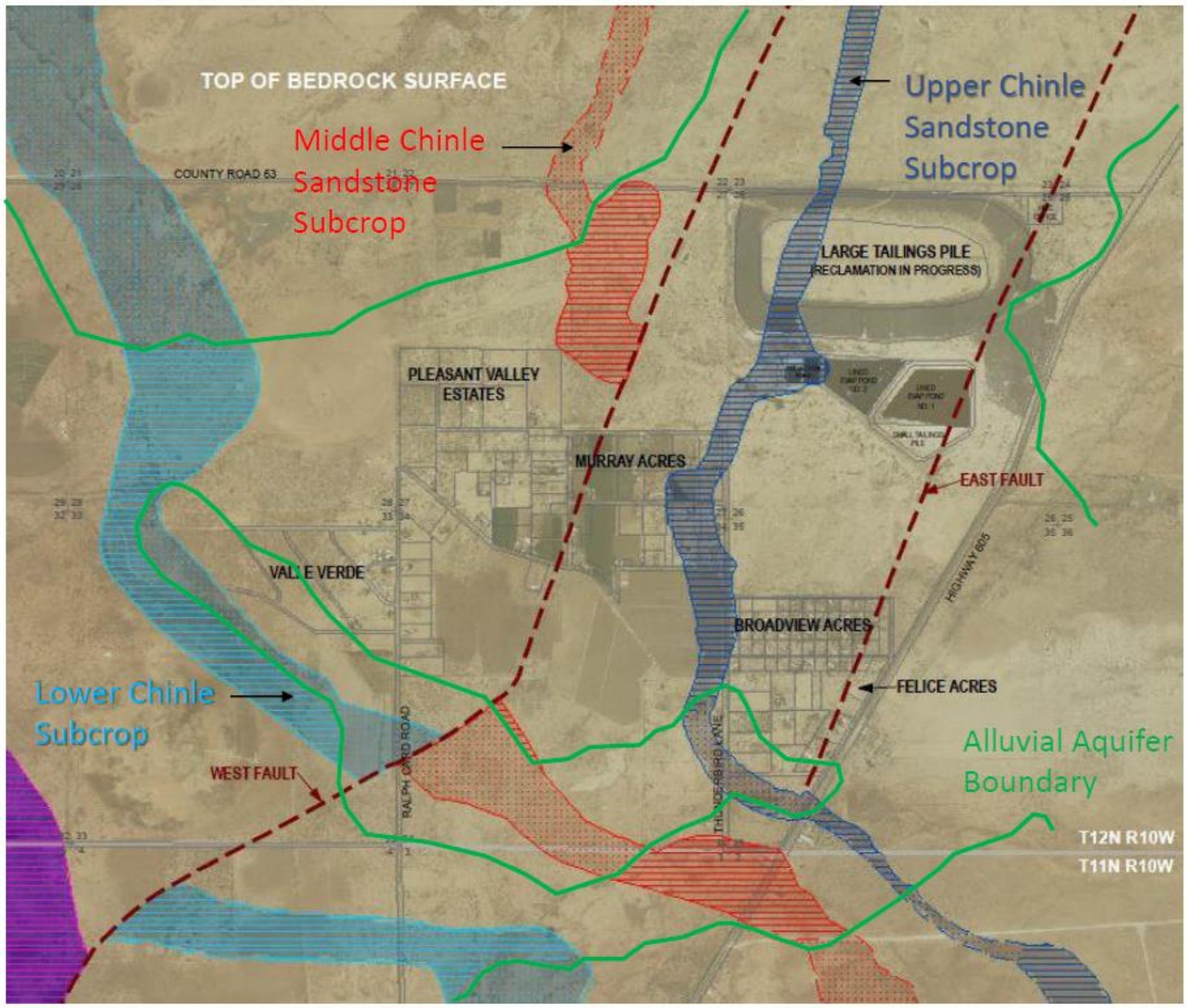

Figure 1: Site map of the Homestake Mill Site showing saturated alluvial aquifer (surrounded by green line), Chinle aquifer subcrops (dark blue for Upper, orange for Middle, and light blue for Lower, horizontal hatching for overlaying saturated aquifer). Source: Background Presentation, Mark Purcell,

Figure 2: Geophysics north of the LTP. Source: Background presentation, Mark Purcell, 9/12/19

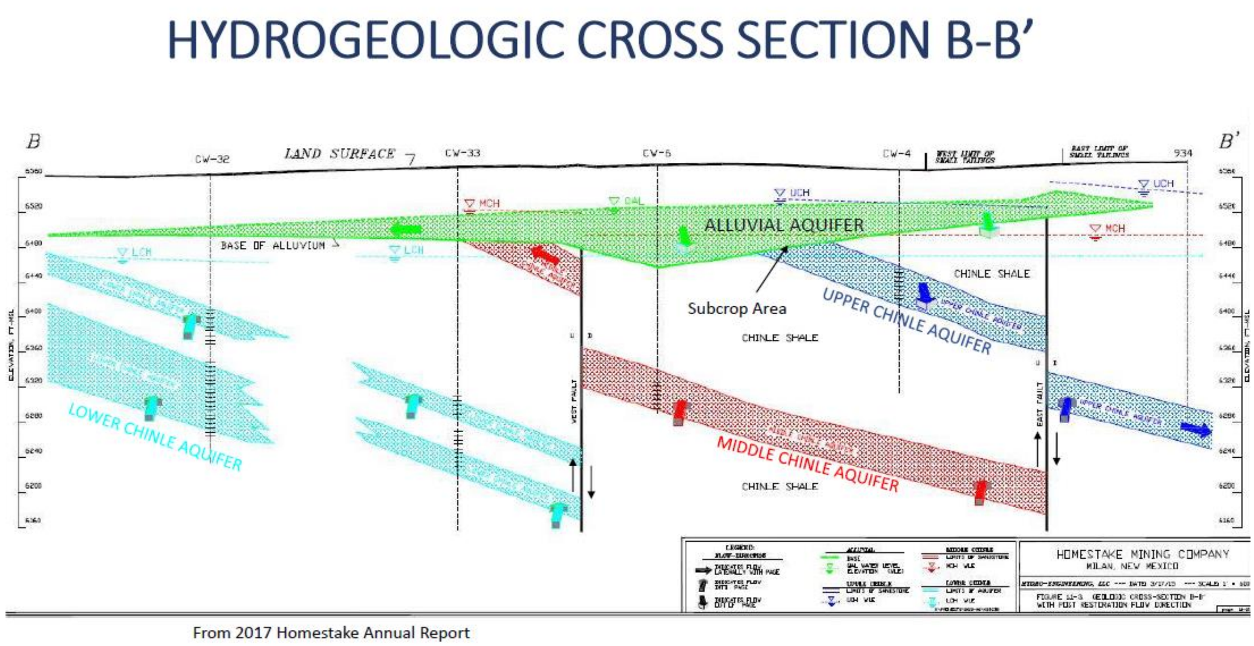

Figure 3: Hydrogeologic cross-section a few hundred feet south of the LTP. Source: Background presentation, Mark Purcell

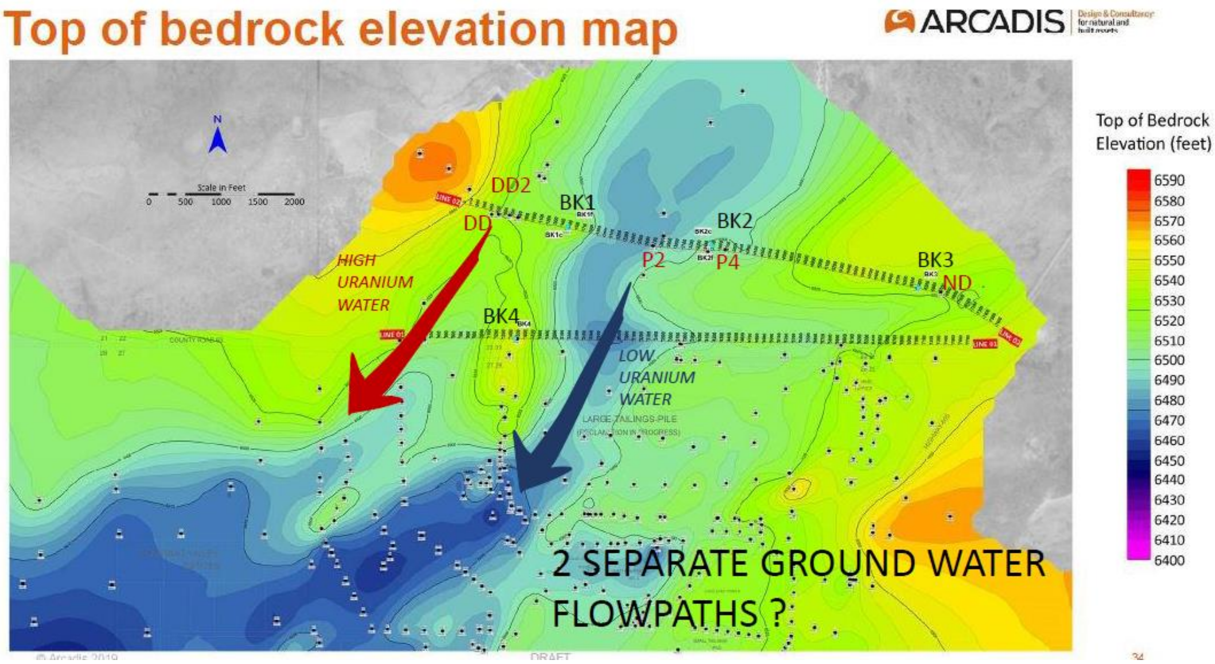

Figure 4: Alluvial flow paths and depth to bedrock. Source: Background presentation, Mark Purcell, 9/12/19

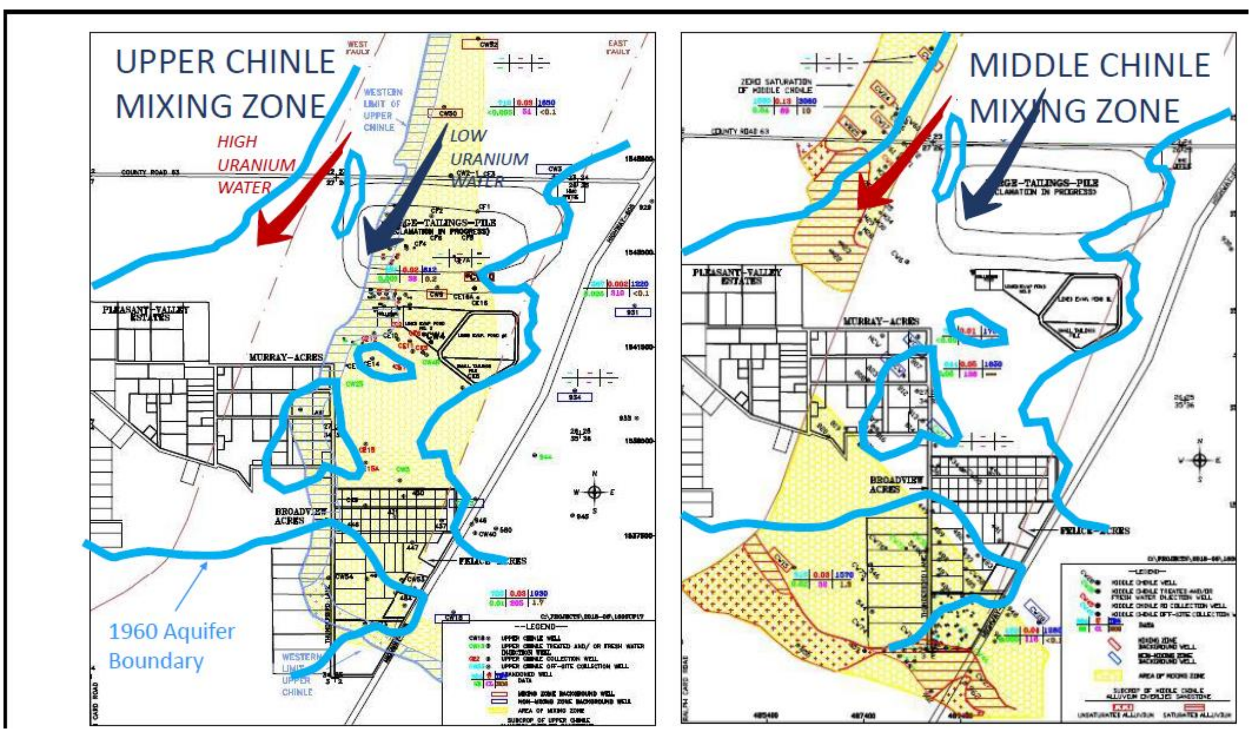

Figure 5: Conceptual flow pathways through the alluvium over the Chinle outcrops. Source: Background presentation, Mark Purcell

Statistical Analysis for Background

NRC (2006) generally set background equal to the 95% exceedance value, which means that 95% of the observed values were less than the selected background. If the data set was parametric, the 95% value was based on statistically setting confidence limits. Non-detect values were adjusted, but because the non-detects are near the low end of the values, it makes no difference if the data set is nonparametric for the determination of the 95% exceedance. High outliers were removed, but there were very few. If the data set was non-parametric, the statistic was set equal to value determined by sorting and ranking the data set. For U, data sets for all aquifer zones were nonparametric and there were no high outliers.

This technical memorandum utilizes similar statistical concepts for estimating background, however the estimates are tempered with qualitative assessments of data that may not be in the same specific sampling used for frequency analysis. The differences between recommendations herein and NRC's recommendations are based on the monitoring wells used to estimate the background. For example, in addition to the statistics, I consider U concentrations at wells with data prior to 1982 since 2004 if justified. Recommendations for background based on statistical analysis are also tempered by an understanding of the CFM. Observations obviously affected by mining or milling are not utilized. Indications of mining effects include trends and spikes in the concentration data.

ALLUVIAL BACKGROUND

Figure 6 shows near-upgradient wells (ND, DD, P, P1, P2, P3, P4, Q and R) and well DD2, far-upgradient wells (914, 016, 920, 921, 922, and 950), and their 2013 water level elevations. HMC used these wells to determine background (NRC 2006). Far-upgradient well water levels are about 20 feet higher than at the near-upgradient wells. The water surface elevations for the near-upgradient wells vary by less than 5 feet with the water levels under the LTP. These water level observations do not contradict the hypothesis presented by Myers (2015) that over time mounding under the LTP could have reversed the gradient and been responsible for high U concentrations in wells upgradient from the LTP.

U concentrations at the far-upgradient wells trend upward which reflects the downstream advection of U from upstream millsites (Figure 7). None have 1970s data, but the earliest observations are less than 0.05 mg/l. Wells 920, 921 and 950 show a distinct upward U concentration trend that does not occur at wells 914 and 922, which lie east and west, respectively, of the other wells. U concentrations at well 916 which begin in the early 1990s are very low whereas concentrations at 921 exceeded 0.15 mg/l. U concentrations at the far-upgradient wells were low, less than 0.03 mg/l, prior to discharge from upstream mines and mills reaching the area.

U concentrations at the near-upgradient wells support Myers (2015) hypothesis that U advection from the LTP caused occasional high U concentrations or spikes in many of the wells between 1975 and about 1985 (Figure 8). After 1985 the concentrations generally decreased to less than 0.06 mg/l, with well DD being an exception. Concentrations at well DD reflect a different source related to U transport that has primarily occurred west of the LTP. Well D2, which was not used for the determination of background U concentrations but lies in the high-U pathway (Figure 4), has high concentrations subsequent to 2008.

Water chemistry data for well DD compared to other background alluvial wells further demonstrates how unusual well DD is. While it has the highest U, it has the lowest Se and highest Ca values (Figure 9). These substantial differences support a hypothesis that the water at well DD originated from a different source than the water at other alluvial background wells (Figure 9 shows wells DD, P, Q, and R because these have a data set that spans the period). The source of the U in the portion of the alluvium that affects groundwater west of the LTP and the subdivisions, upgradient mines and milling or natural sources, is not relevant to background throughout the remainder of the alluvium.

HMC calculated background U concentrations using data from 1995 through 2004 for the near-upgradient wells. It is unknown whether these data represent pre-milling conditions because residual U from LTP mounding could be causing higher concentrations. There is no apparent trend that would reflect residual U slowly decreasing. Simply stated, it is not known whether 1995 through 2004 near-upgradient U concentrations are representative of background. However, trends in the paleochannel represented by DD and DD2 show that data from DD is not representative of background. DD at least shows that the western portion of the alluvium is affected by different flow sources than most of the alluvium. The trend at DD that shows significantly lower values in the 1970s shows that values observed at that well between 1995 and 2004 are not at all representative of background.

The geographic variability in the alluvial data indicates that setting a single value for background for an entire aquifer is difficult. Water quality changes from the point of recharge to discharge under natural conditions based on the mineralogy of the rock through which the flow occurs. Different mineralogy could substantially affect different portions of an aquifer. Well DD apparently represents a different portion of the alluvial aquifer and the high concentrations could be natural or due to advection from upstream. Groundwater at DD cannot reach the groundwater under the LTP or southwest of the LTP, the area for which the background determination is essential.

Frequency plots of the near-upgradient well data for 1995 through 2004 show the major effect on calculated background caused by well DD (Figure 10). With DD data, the 95% exceedance is about 0.16 mg/l which corresponds to the Homestake-estimated background, but without DD, it is about .054 mg/l. The higher U values occur at well Q which exhibits relatively stable values around 0.05 mg/l after some fluctuation prior to 1985 (Figure 8). The median value for each is about 0.03 mg/l.

HMC sampled many alluvial wells throughout the alluvial aquifer system in 1976. The data includes wells in the subdivisions downgradient from the LTP; the wells beneath the LTP were massively affected by tails leakage prior to the first samples in 1976. In alluvial wells, high U concentrations occurred in the subdivisions south of the LTP. The highest concentrations were most noticeable in the Felice Acres area, an area which still experiences U concentrations exceeding 0.16 mg/l (HMC 2019). I discuss this contamination in more detail below in the Middle Chinle non-mixing zone section and Figure 17. The earliest U concentration data ranges from non-detect to greater than 10 mg/l. Only the non-detect values could truly represent background in an area with such a variety of U concentrations.

A reasonable background value for U in the alluvium is 0.04 mg/l based on three factors. The 95% exceedance value at the near upgradient wells without well DD is 0.05 mg/l. However, the far upgradient wells and wells southwest of the LTP commenced at concentrations less than 0.03 mg/l but there are few observations from either point. Due to the limited number of observations, it is difficult to include this data in a frequency distribution using near upgradient wells for which there are many observations. Statistics based on many observations at some wells and few at others are controlled by the wells with many observations. Therefore, I adjusted the 95% value determined using statistics for the near upgradient wells to a recommended background equal to 0.04 mg/l.

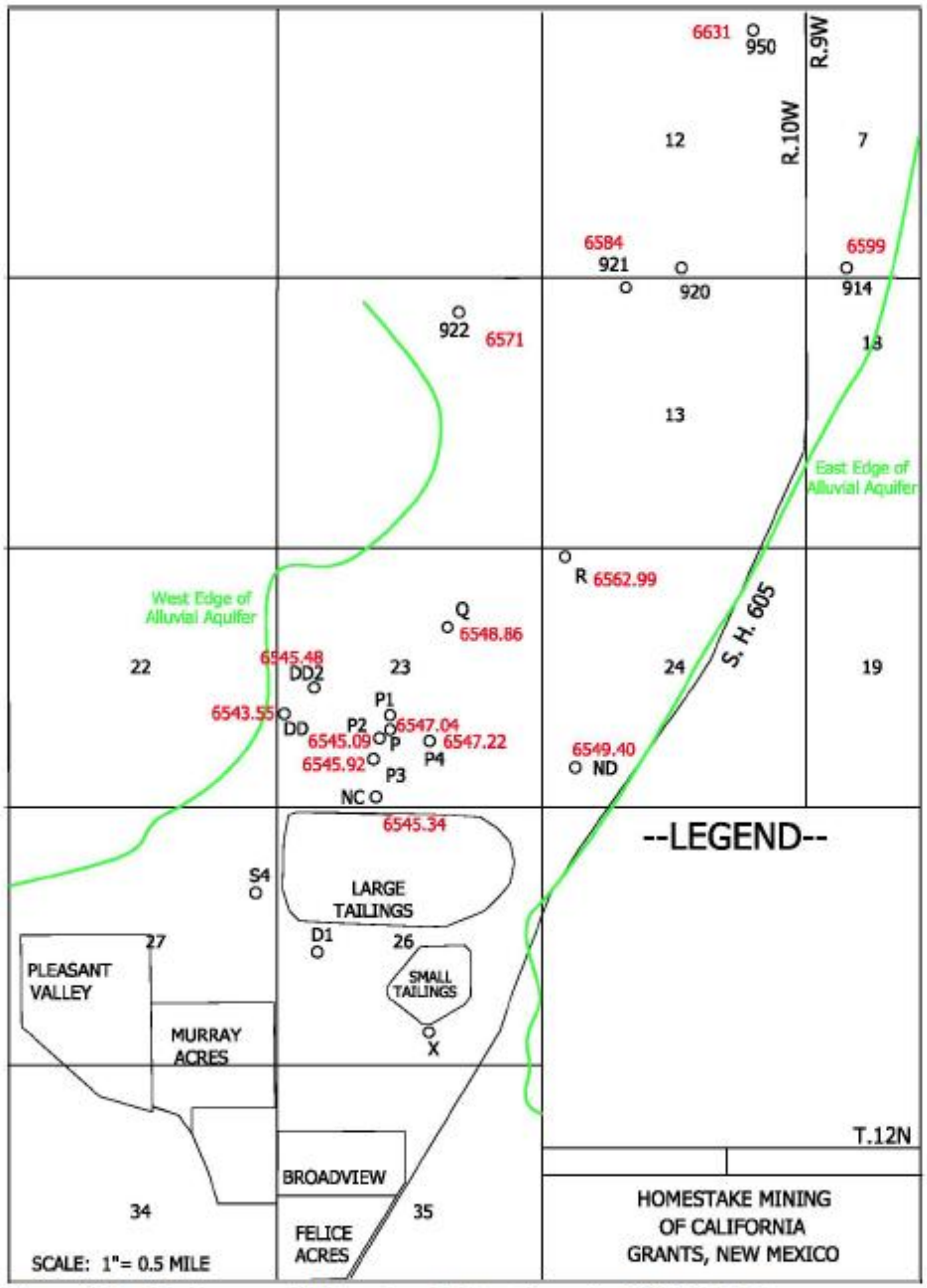

Figure 2-3. Background Water-Level Elevations in 2013, ft-MSL

Figure 6: Location and groundwater level elevation of near and far-upgradient alluvial wells near the Large tailings pile. Source: Homestake (2015) Figure 2-3.

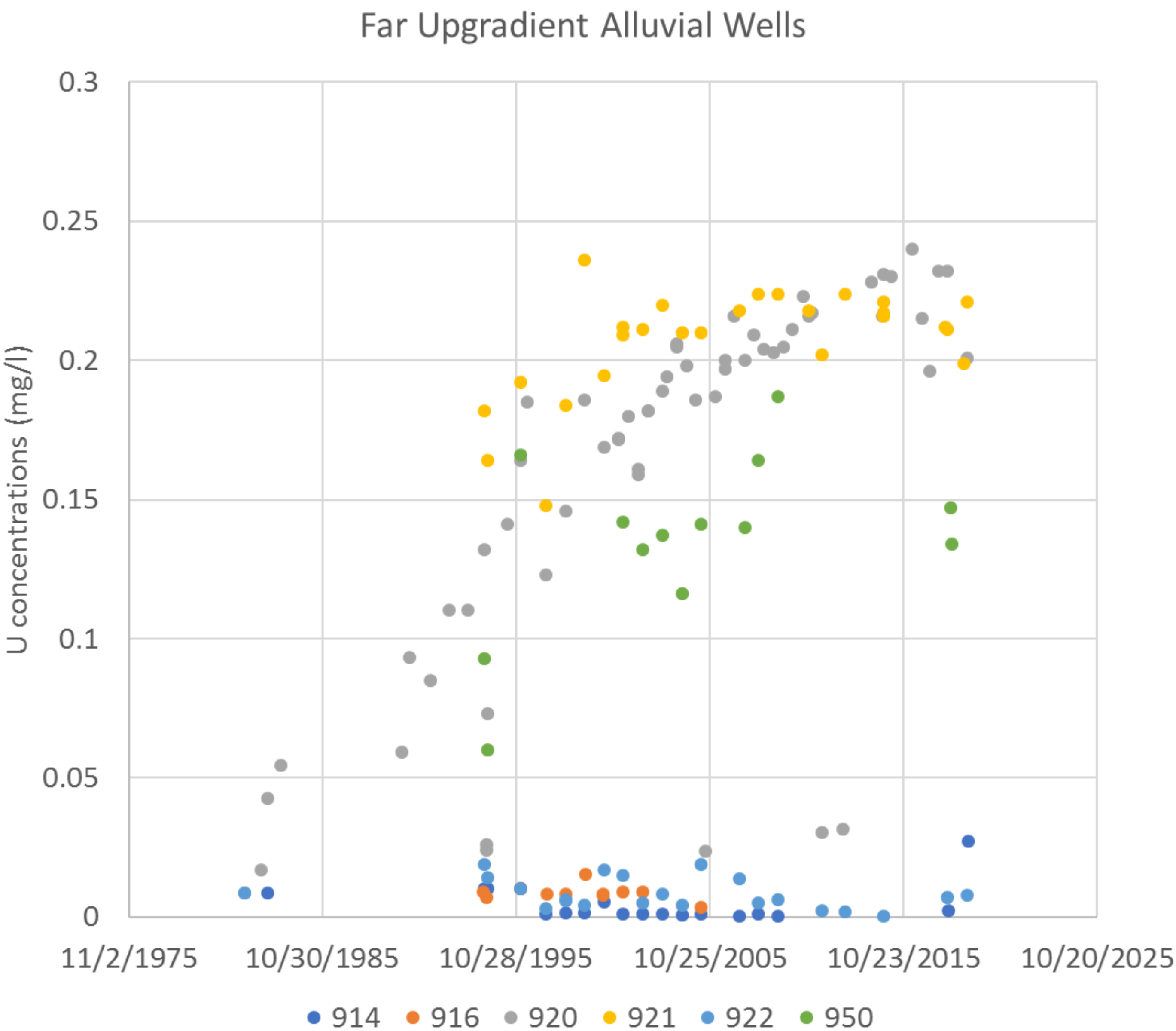

Figure 7: Uranium concentrations for the far-upgradient alluvial wells. Source of data: Homestake digital groundwater chemistry database

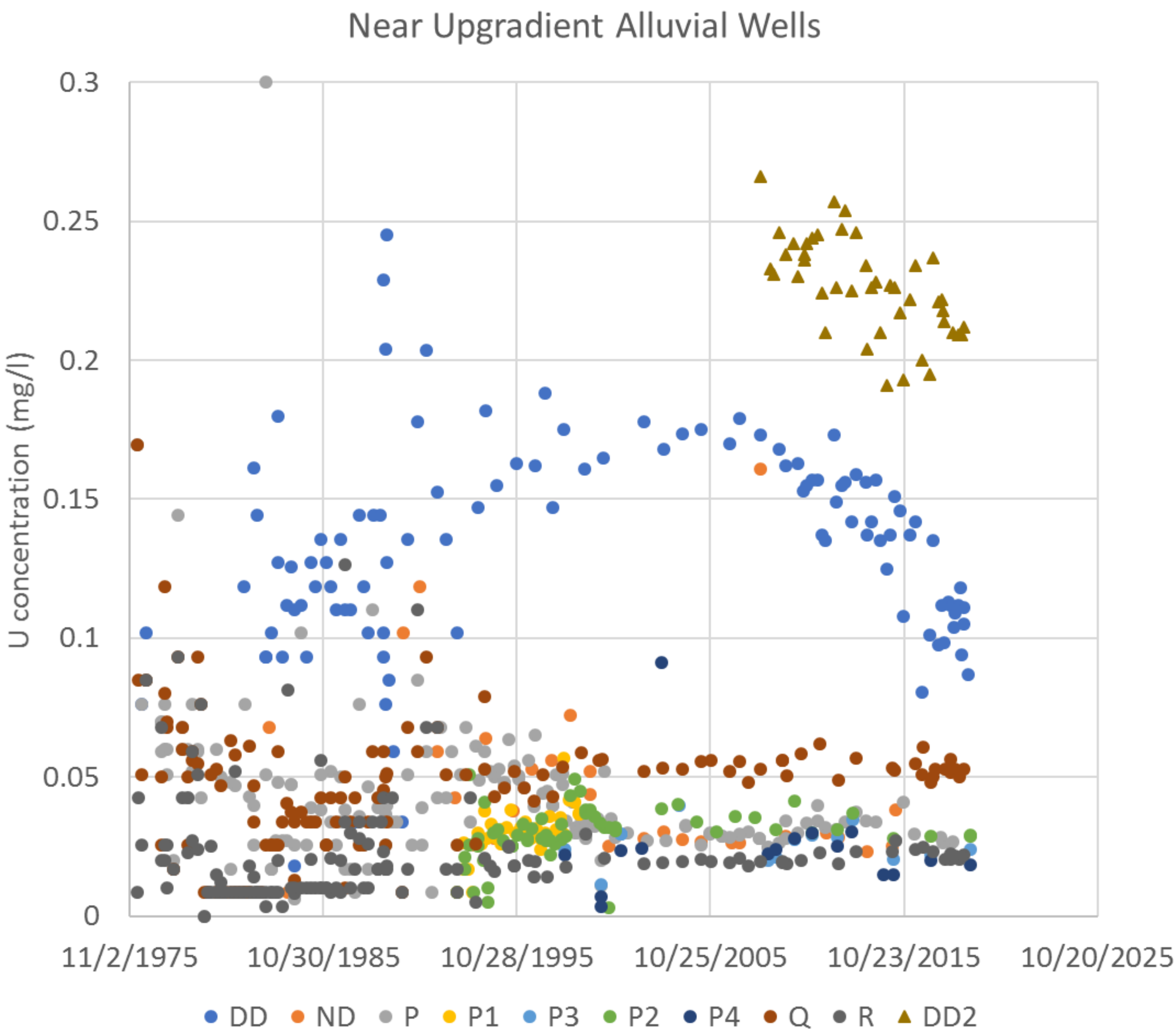

Figure 8: Uranium concentrations for the near-upgradient alluvial wells. Source of data: Homestake digital groundwater chemistry database

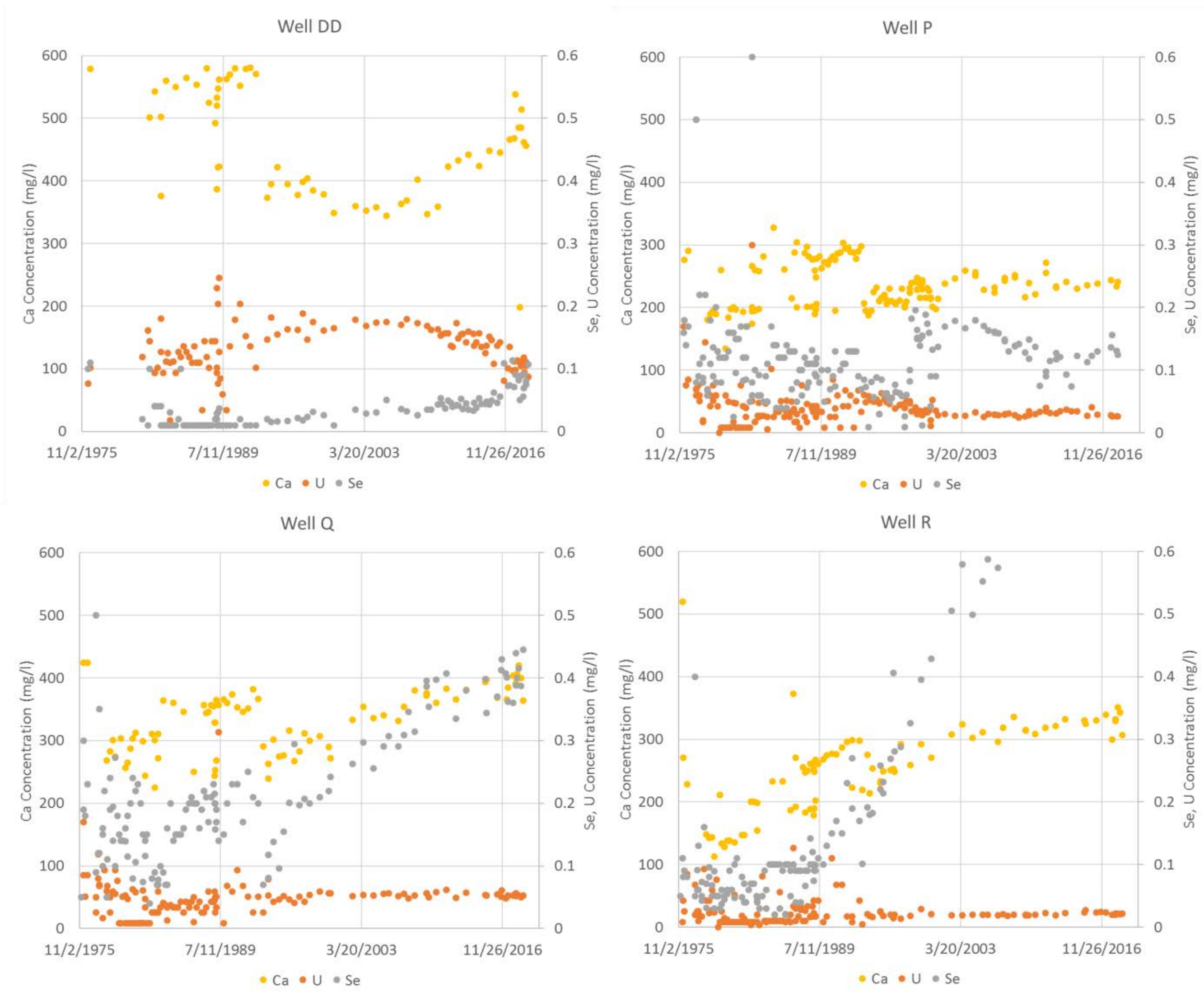

Figure 9: Comparison of water chemistry at well DD as compared with wells P, Q and R. Data source: HMC database

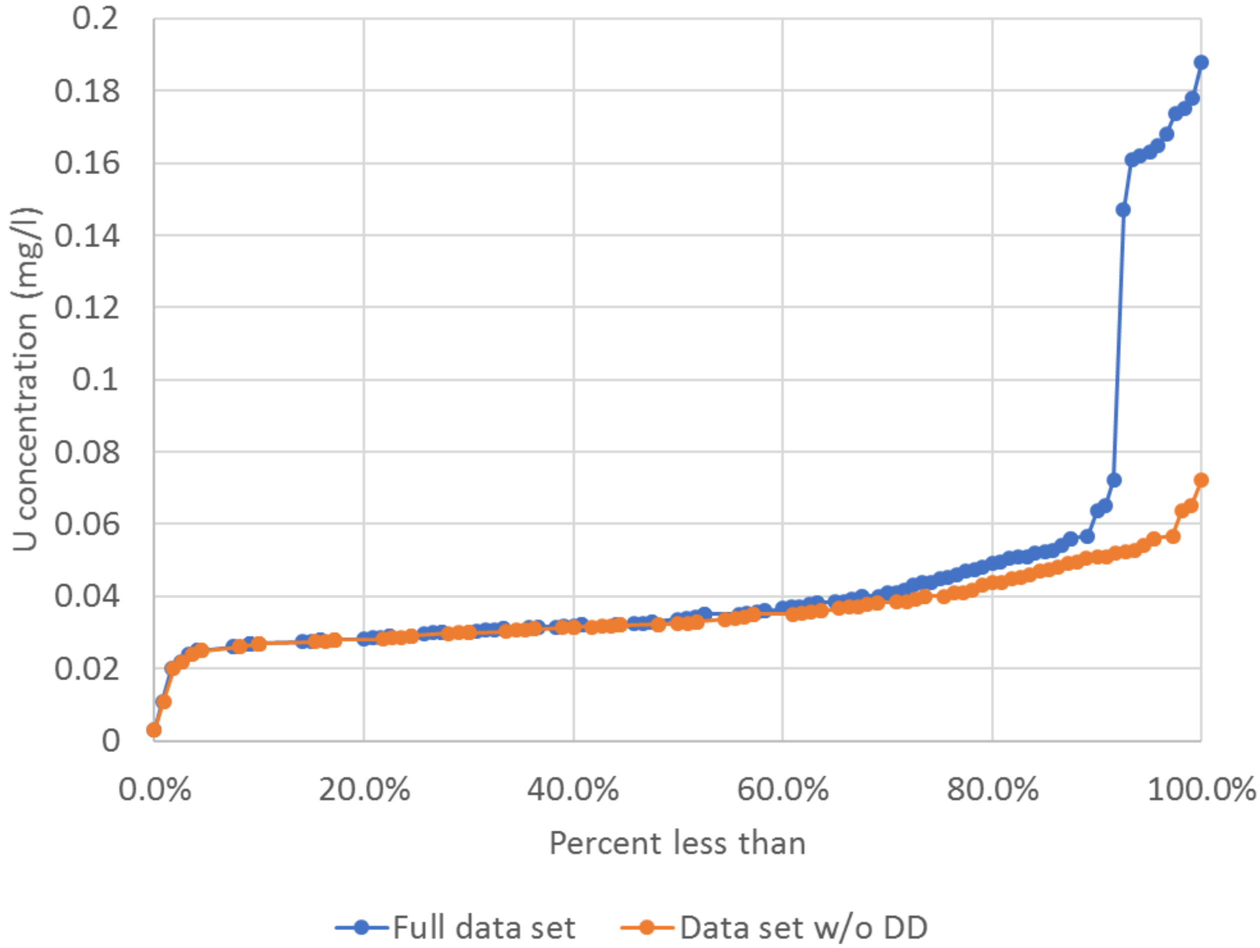

Figure 10: Percent exceedance plot for the near upgradient wells from 1995 through 2004, with and without well DD. Data source: HMC database

CHINLE FORMATION BACKGROUND

The Chinle formation has three water-bearing zones, the Upper, Middle and Lower Chinle aquifers. Each zone subcrops under the alluvium, so alluvial water flows into the different zones, depending on water levels in each zone. Each therefore has a mixing zone where the water chemistry closely reflects that in the alluvial zone. HMC delineated mixing zones for each Chinle member based on calcium concentrations being much higher than it is deeper in the aquifer. The cutoff was set at 30 mg/l. Calcium concentration is naturally higher in the alluvium and calcium is also geochemically conservative, so basing mixing zones on calcium concentrations is reasonable.

HMC proposed background concentrations for the three separate Chinle zones and the Chinle mixing zones considered as one. With respect to background U concentration, the implicit assumption is that the mixing zone background is affected by the background conditions in the alluvium. Figures 1, 3, 10, 13 and 17 show the three Chinle aquifers and mixing zones. The following discussion is by Chinle zone followed by discussion of the mixing zone.

Upper Chinle Zone

The Upper Chinle is the uppermost water bearing zone within the Chinle formation beneath the LTP. The aquifer dips east from the subcrop. The flow direction is generally north to south, meaning the area north of the LTP is primarily upgradient. The mixing zone is a large portion of the entire aquifer from the subcrop to the East fault (Figure 11), which presumably prevents natural mixing from extending further east. HMC determined background equal to 0.09 mg/l using observations from six wells (Figure 12) from 1983 through 2003.

Prior to 1987, all Upper Chinle HMC background well concentrations are less than 0.04 mg/l (Figure 12). Between 1987 and the early 1990s, there was a rapid increase up to close to 0.1 mg/l. Starting around 2003, one well, CW3, increased to as much as 3 mg/l. All Upper Chinle monitoring wells show influence from millsite alluvial uranium starting around 1985 (Figure 12). This is due to seepage from the LTP into the alluvium in the 1970s reaching the Chinle in the time it takes to reach the base of the alluvium.

Wells CW3 and 931, close to the northeast corner of the LTP and southeast of the LTP, have low concentrations prior to 1985 but then trend upward (Figure 12). These wells have low U concentrations early in the period because they are far from the subcrop. Measurements at well 934, further southeast of the LTP, started a few years later at concentrations similar to CW3 and 931. CW18 concentrations started at over 0.14 mg/l and dropped through the years as cleaner water entered the aquifer.

Mixing zone wells for the Upper Chinle show concentrations that are generally less than 0.06 mg/l (Figure 13). Two of these wells (CW9 and CW10) are directly beneath the south portion of the LTP and two (CW50 and CW52) are substantially north of the LTP. Further east and south, spot measurements in the mixing zone show how U contamination spread into the Upper Chinle. Three wells from the Felice Acres area show substantial increases from background to concentrations reflecting seepage. Well 445 had U equal to 0.025 mg/l in 1976 before rising to over 1.6 mg/l in 1982. In 1981 well 485 U was non-detect U. In 1983, well 486 had U concentrations equal to 0.019 mg/l. These measurements which preceded substantial increases in U in the Upper Chinle in Felice Acres reflect background before any impact.

Most wells have been affected by LTP leakage through the years. However, the nonmixing zone Upper Chinle wells may be affected by a different flow pathway than affects the mixing zone. Because the U concentrations in the Upper Chinle beyond the mixing zone have become higher than in the mixing zone, the pathway is probably the East Fault. The variability of the U concentration data and the location of the monitoring wells relative to the subcrop and the East Fault indicate that none of the U data can truly represent background not affected by leakage from the LTP.

U concentrations for wells CW3 and 931, which are apart from the East Fault and the subcrop, are least affected by tailings seepage and therefore are most likely to represent natural background. A reasonable background for the Upper Chinle non-mixing zone is 0.03 mg/l based on concentration data prior to 1987 at CW3 and 931.

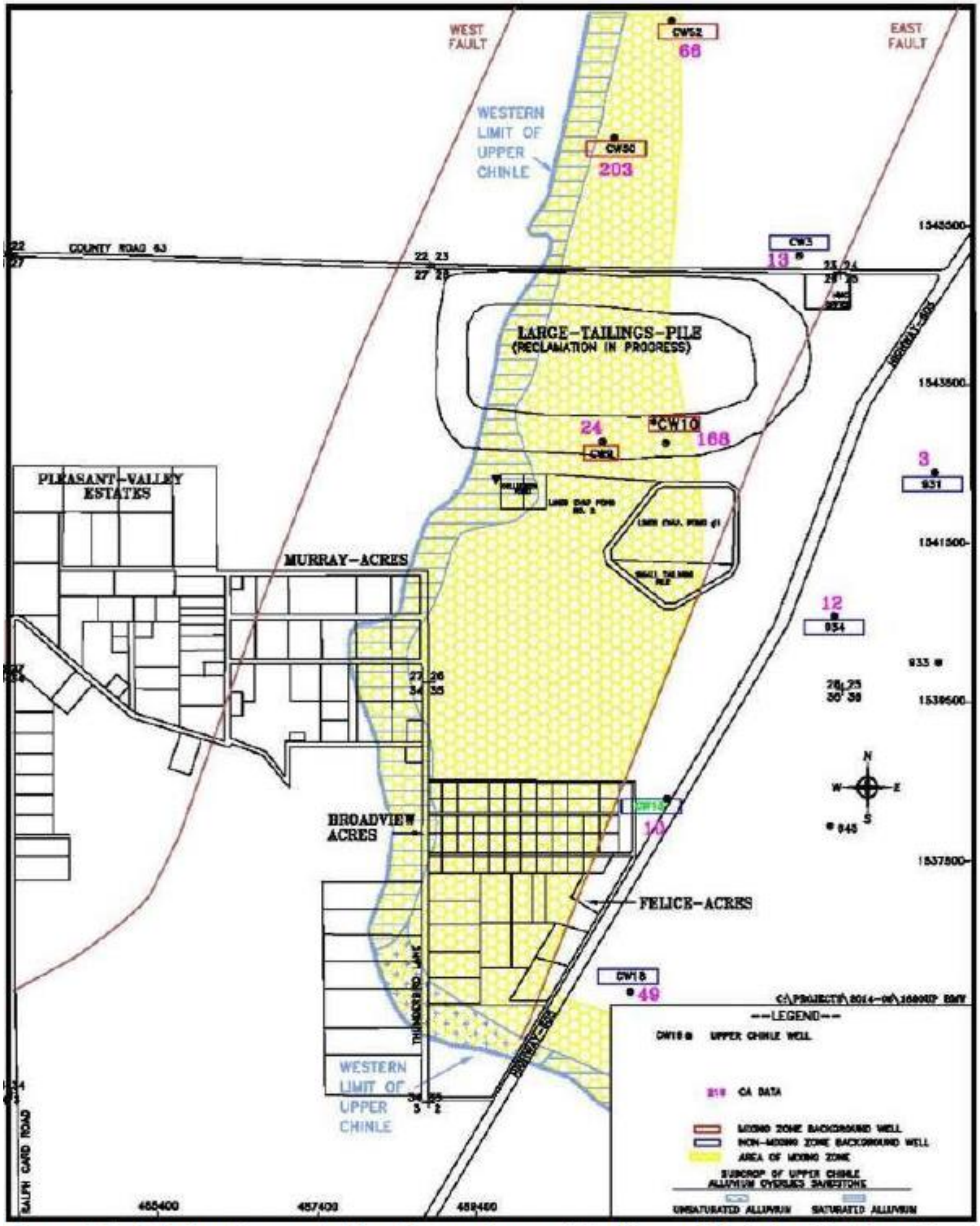

Figure 6-1. Calcium Concentration Comparisons of the Upper Chinle Aquifer in mg/l

Figure 11: Monitoring wells, calcium concentrations, and mixing zone delineation in the Upper Chinle aquifer. Source: HMC (2015) Figure 6-1

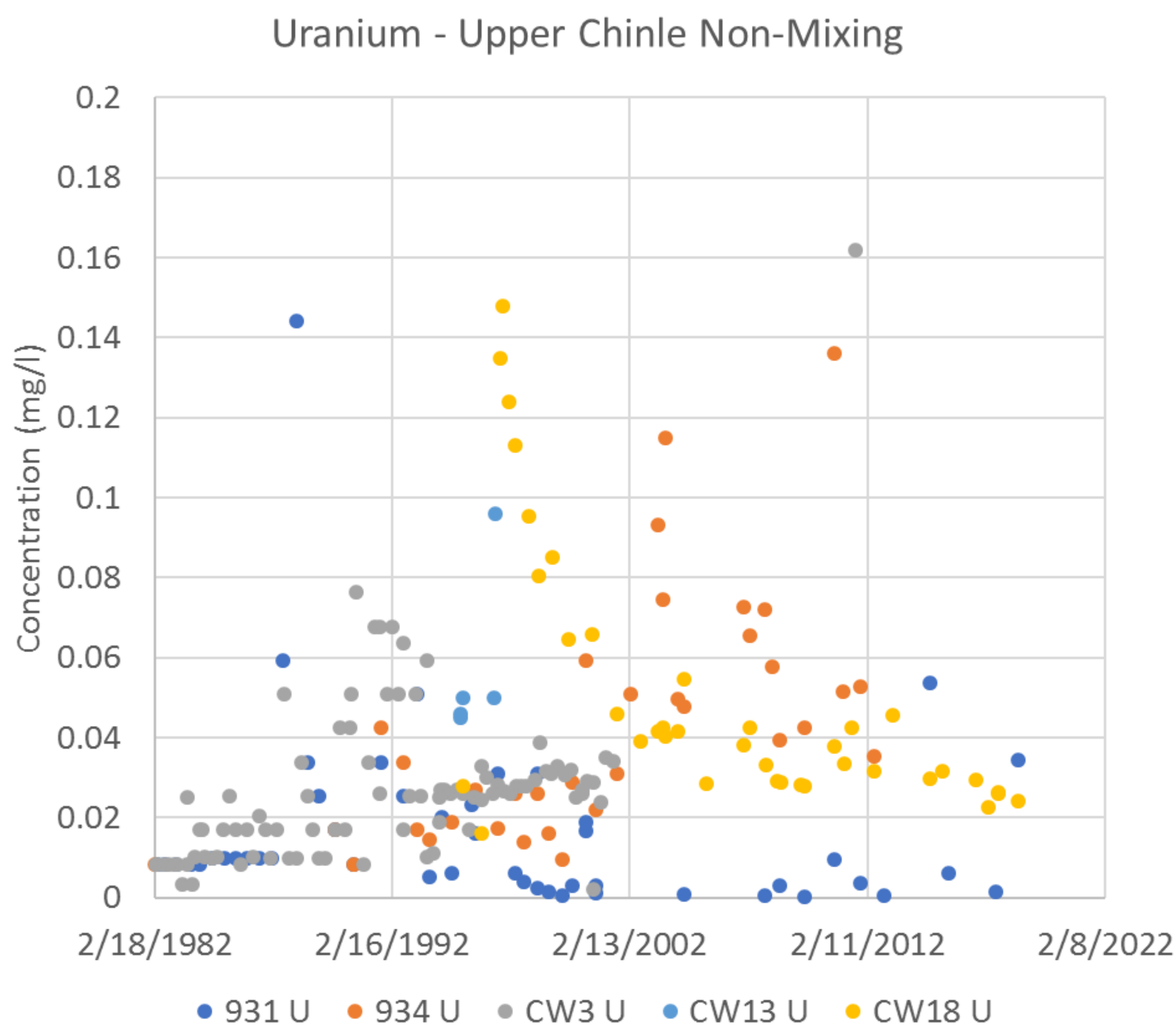

Figure 12: Uranium concentrations for the Upper Chinle zone wells. Observations for well CW3 that are higher than 0.2 mg/l, some as high as 3.0 mg/l, after 2002, are not shown. Source of data: Homestake digital groundwater chemistry database

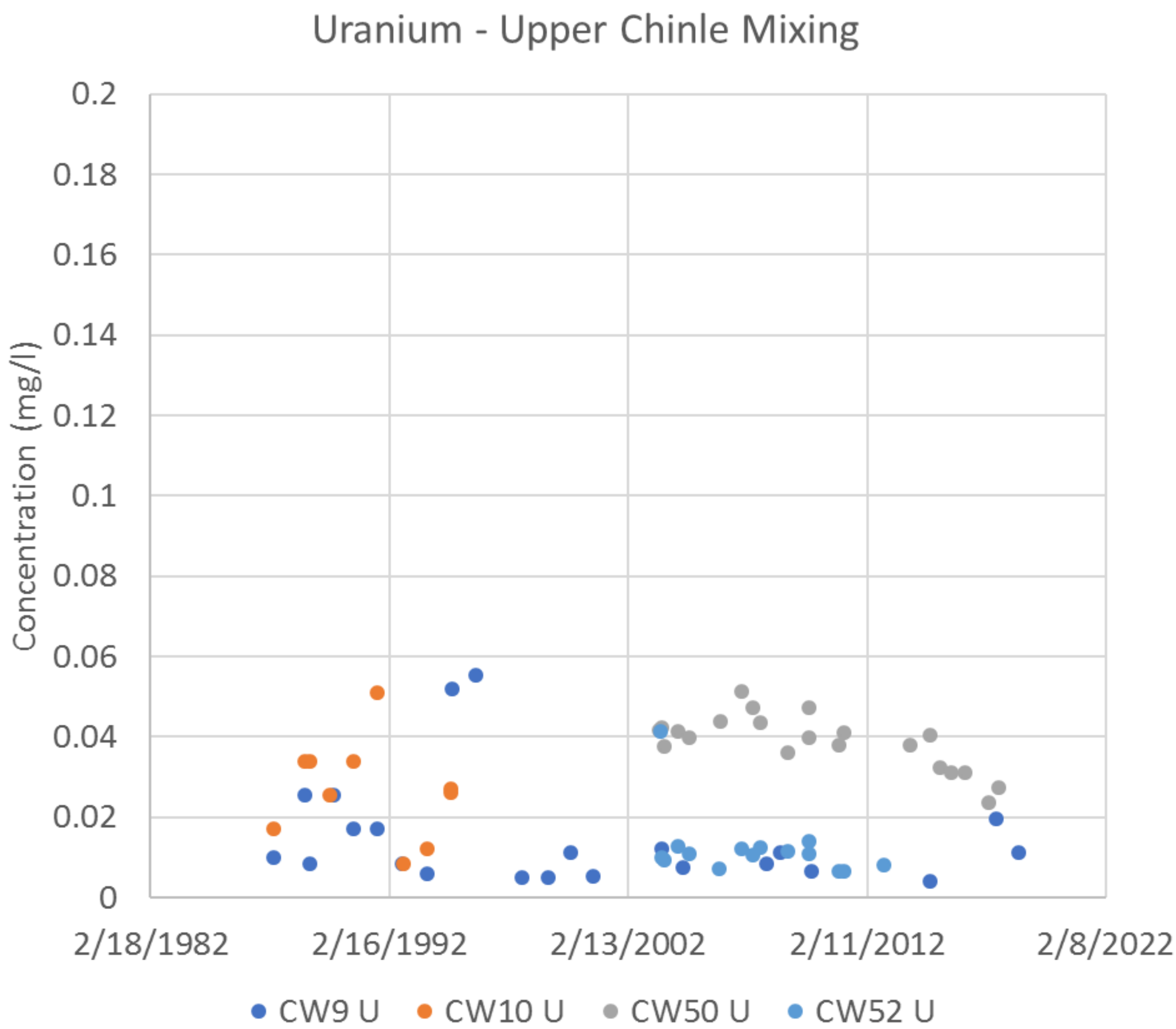

Figure 13: Uranium concentrations for the Upper Chinle mixing zone wells. Source of data: Homestake digital groundwater chemistry database

Middle Chinle Aquifer

The Middle Chinle aquifer subcrops under saturated alluvium directly west of the West Fault west of the LTP and in the area between the faults south of Broadview Acres (Figure 14). The subcrop is under the alluvial flow path that has high U concentrations (Figure 4). West of the West Fault, groundwater flow is northeast to southwest whereas between the two faults and east of the East Fault, flow is south to north (HMC 2015). HMC claims there is flow is from the Middle Chinle to the alluvium, but data presented in the 2018 annual report (HMC 2019) regarding water levels is inconclusive. Middle Chinle water levels shown on HMC (2019) Figure 6.2-1 are several feet lower than those shown for the alluvial aquifer (HMC 2019, Figure 4.2-1). However, the Middle Chinle water levels are affected by hydraulic control pumping, as evidenced by closed contours west of the West Fault and of the LTP. Pumping and injection could confuse the interpretation of general groundwater flow between aquifers. However, no data in HMC 2015 supports the HMC claim. Also, HMC (2019) states the U source to the Middle Chinle is downward flow from saturated alluvium.

Most U concentrations at four Middle Chinle nonmixing wells south of the LTP are less than 0.05 mg/l (Figure 15). The exceptions are five observations at CW28 between 1997 and 2000 and one observation at ACW and WCW during 1982 and 1983. U concentrations at CW1 and CW2, which are just north of the LTP (Figure 14), trended up with time, showing a clear effect of leakage from the LTP which could have reached the Middle Chinle without passing through a mixing zone but by seeping through the Middle Fault (fault shown on Figure 2 but not on Figure 14).

The Middle Chinle has two mixing zones, with one west of the West Fault and one near the subcrop at the southern boundary of the Middle Chinle between the faults. U concentrations at the four wells in the northern mixing zone, WR25, CW17, CW24 and CW35 (Figure 14), exceed 0.06 mg/l with no significant temporal trend (Figure 16). However, these data are more recent than 1992 which suggests that the same source affecting well DD in the alluvium could have affected these wells (Figure 4). All but two observations at mixing zone well CW15 in the southern mixing zone are less than 0.04 mg/l and the two exceptions are less than 0.05 mg/l (Figure 16). The alluvial aquifer over the southern mixing zone is not contaminated.

Middle Chinle well data from 1982 through 2002, not including CW1 and CW2, has a 95% exceedance of about 0.068 mg/l. If the five anomalous data points at CW28 are removed, the 95% exceedance would be about 0.05 mg/l and if the 1982 and 1983 points are removed, it would be close to 0.04 mg/l. The median value is 0.01 mg/l due to many non-detects. Since 2002, all data other than from CW1 and CW2 are less than 0.035 mg/l excepting three data points at ACW which are a little higher than 0.04 mg/l. U concentrations in the Middle Chinle nonmixing zone have decreased with time which indicates that removing the anthropogenic source allows the aquifer to return to its natural background. This would not likely have occurred if natural factors worked to keep the U concentrations high.

The HMC database contains many Middle Chinle observations from prior to the period used by HMC for determining background. Most yielded very low U concentrations. Wells in Murray Acres and Broadview Acres have generally low U concentrations with small increases beginning in the early 1980s (Figure 18). In Felice Acres the earliest well U concentrations were very high, with wells 0482 and 0483 exceeding several mg/l. In 1980, well 0482 had 6.5 mg/l and 2.95 mg/l in 1981. Well 0483 increased from 2.6 in 1979 to as high as 12.3 mg/l before 1982. Other wells, including 0481, 0484, and 0486 had low concentrations beginning in the early 1980s but they began to increase with some reaching 1 mg/l by the mid-1980s (Figure 18). Well 0486 increased from 0.019 in 1983 to 1.022 mg/l in 1995. Well 0436 increased from 0.017 mg/l in 1976 to 1.68 mg/l in 1982. Wells 0482 and 0483 lie in the middle of Felice Acres and appear to be the centroid of a contamination source from which U has migrated to other wells in the subdivision (HMC 2019, Figure 6.1-1).

HMC (2019) claims the U source in the Middle Chinle south of the LTP is seepage from the alluvium, suggesting a pathway of U to the alluvium and then into the Middle Chinle through the subcrop south of the LTP. CH2MHill (2001) described both seepage and windblown tailings as a contaminant source for alluvial groundwater, but no documentation has been found for the high concentrations in Felice Acres. That the concentrations are much higher in the Middle Chinle than in the alluvium and the locations are not near the mixing zone contradicts the hypothesis of the alluvium as the initial source. Regardless, the high U concentrations suggests there was a temporary but very substantial U source in these subdivisions in the late 1970s. There are several possible explanations.

The first is for seepage through a fracture into the Middle Chinle somewhere north near the LTP and then advection to the Felice Acres area. There are few Middle Chinle wells between the LTP and the subdivisions, so there is no data to support this hypothesis. It is also unlikely because of how the contamination begin in a centralized location.

Another possibility is that a spill into the alluvium reached the Middle Chinle, but the fact the concentrations in the alluvium are lower than in the Middle Chinle and that concentrations in the Middle Chinle are much higher and geographically concentrated at first do not support this hypothesis. Additionally, the subdivisions are north of the Middle Chinle mixing zone which means there is a layer of Chinle formation between the contaminated alluvium and Middle Chinle that is not considered conducive to flow. The only possible pathway would be through an unidentified fracture or possibly through a well connecting each aquifer.

HMC commenced injection operations in the late 1970s to prevent the spread of U in the Middle Chinle (CH2MHill 2001). These high concentrations are not background but earlier non-affected well observations could be background.

A fair background level for the nonmixing zone Middle Chinle aquifer would be 0.04 mg/l, based on frequency analysis of HMC's Middle Chinle well data from 1982 through 2002 excepting wells and observations described above. It also accounts for the many Middle Chinle wells in the three subdivisions with very low concentrations early in the period by using a lower estimate even though the data is not amenable to being added to the frequency analysis. Using this data accounts for the fact that U concentrations are variable, but most were initially very low. Higher U in the Middle Chinle that occurred subsequent to low concentrations resulted from contamination in the alluvium and should not be considered background.

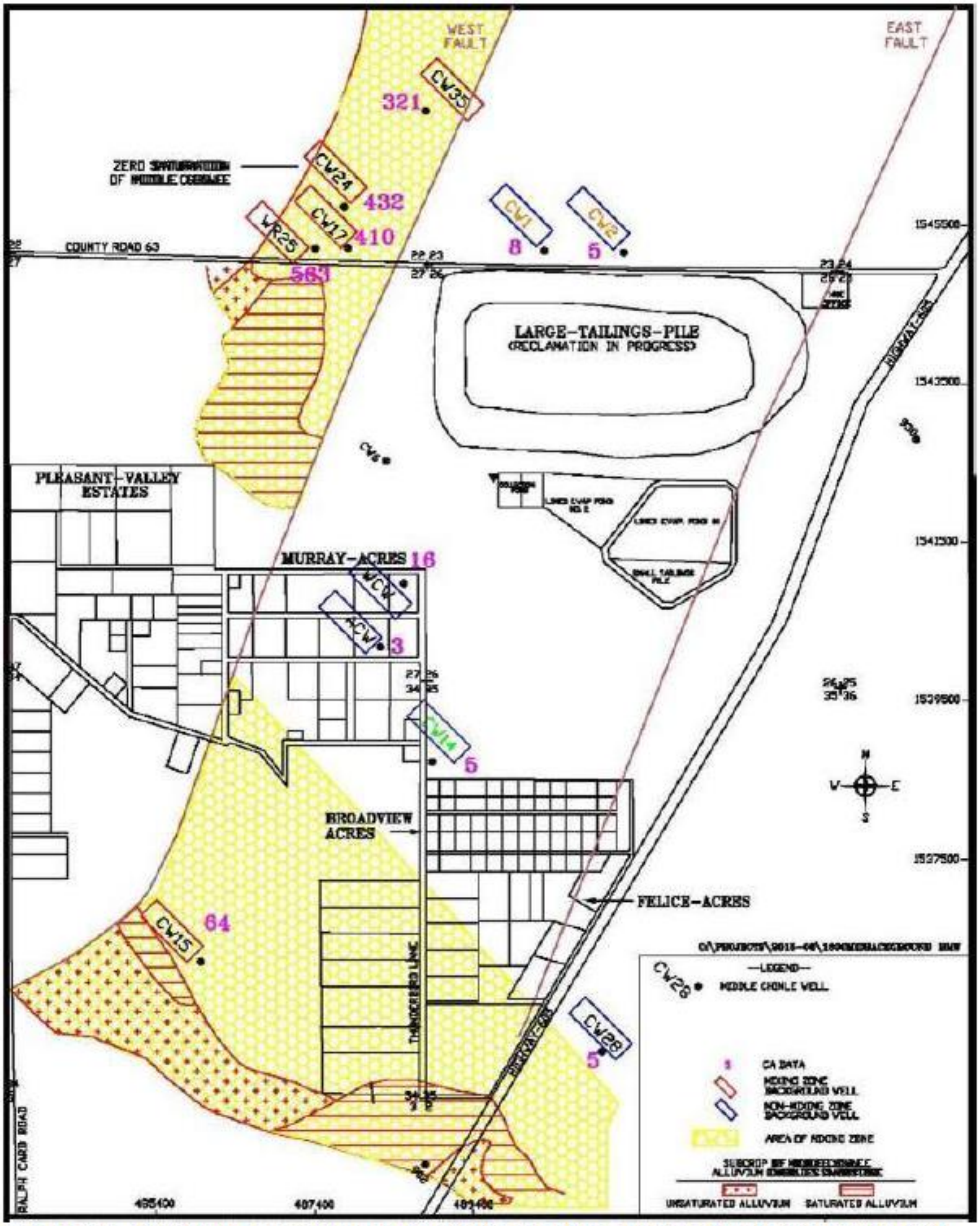

Figure 6-2. Calcium Concentration Comparisons of the Middle Chinle Aquifer in mg/l

Figure 14: Monitoring wells, calcium concentrations, and mixing zone delineation in the Middle Chinle aquifer. Source: HMC (2015) Figure 6-2

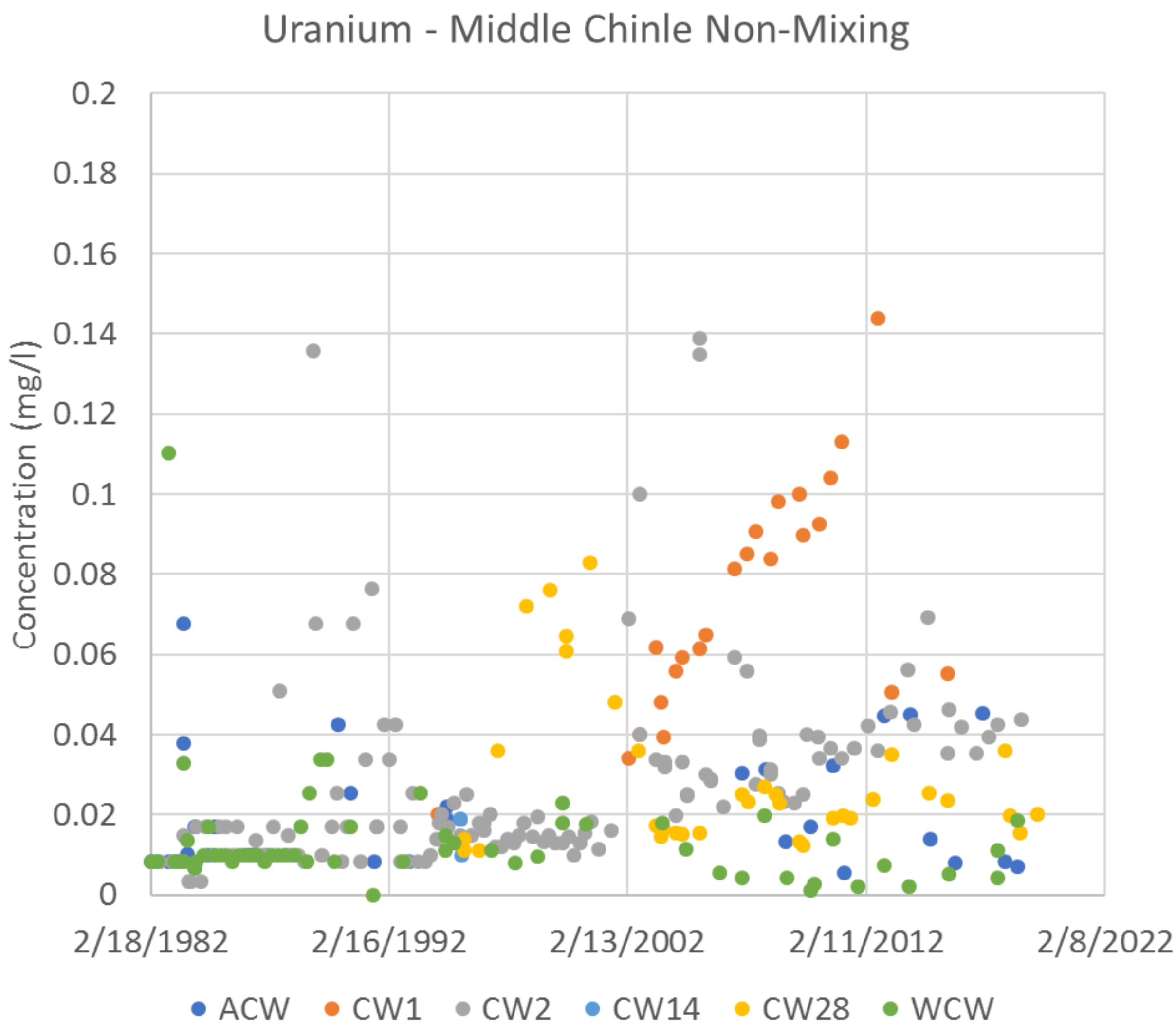

Figure 15: Uranium concentrations for the HMC Middle Chinle non-mixing zone wells. Source of data: Homestake digital groundwater chemistry database

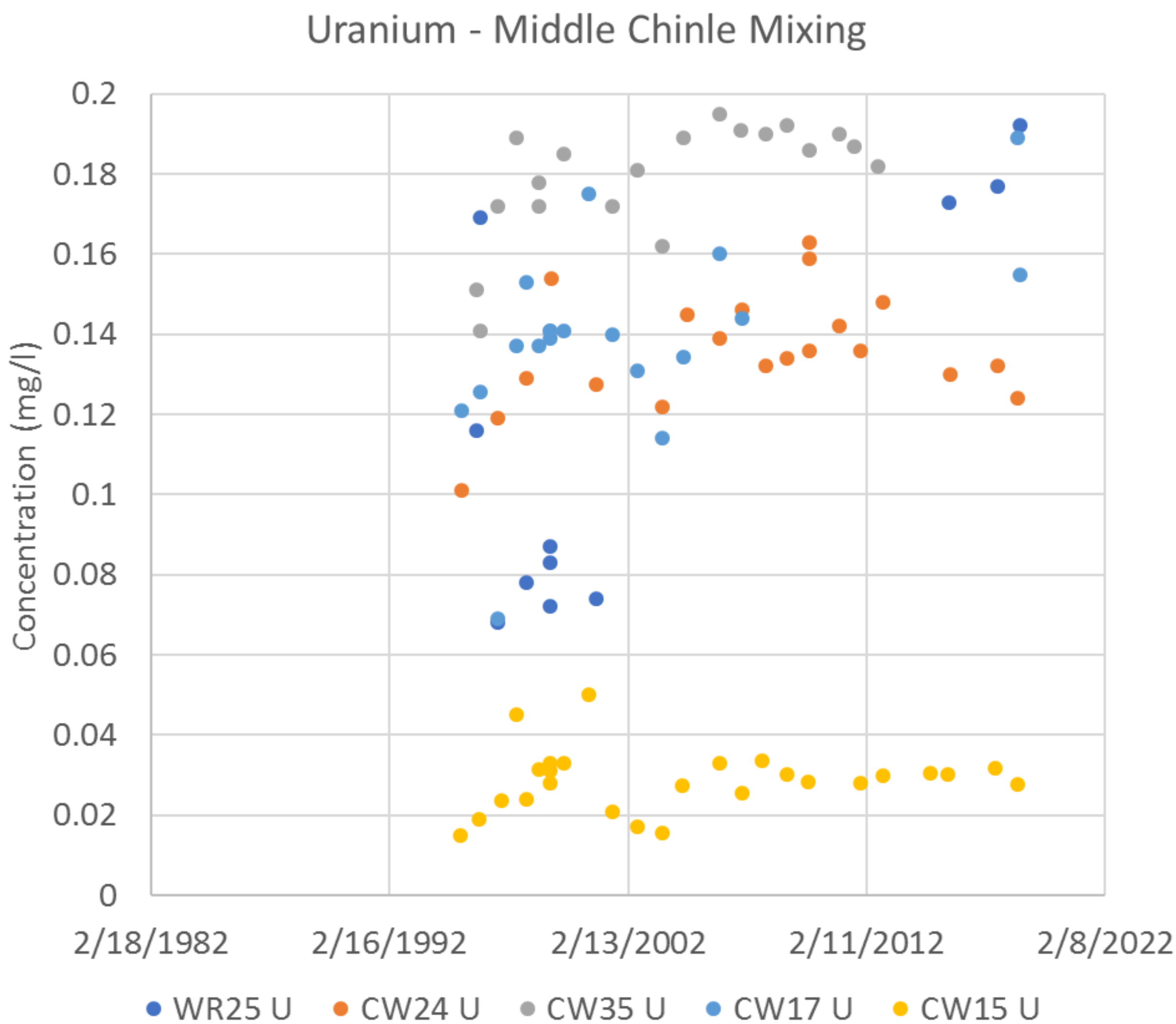

Figure 16: Uranium concentrations for the Middle Chinle mixing zone wells. Source of data: Homestake digital groundwater chemistry database

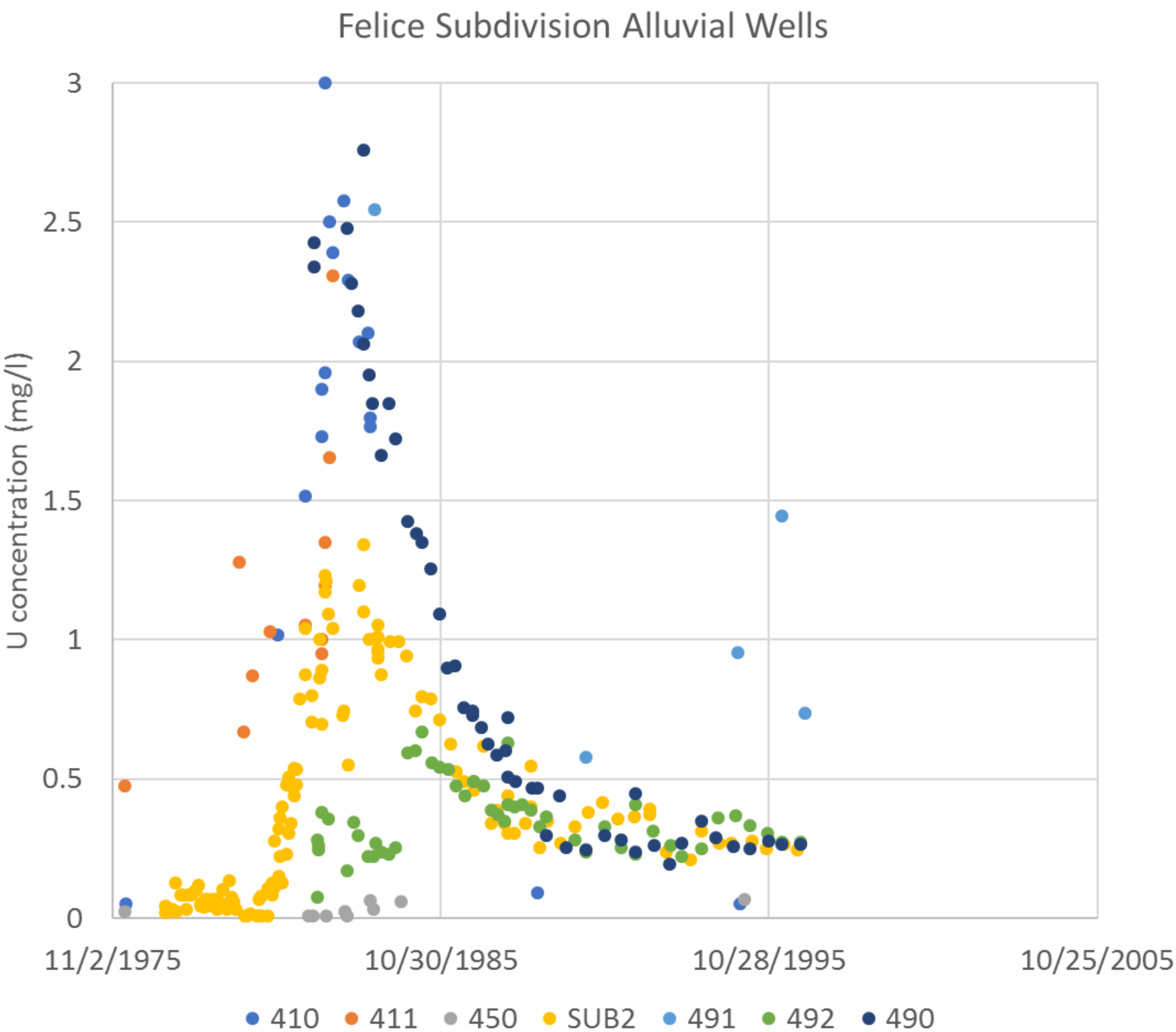

Figure 17: Uranium concentrations for Felice Subdivision Alluvial Wells. Source of data: Homestake digital groundwater chemistry database

Figure 18: Uranium concentrations for Middle Chinle wells for various subdivisions south of the LTP. Notice the different vertical scales. See HMC (2019) Figure 6.1-1 for well and subdivision locations. Source: Homestake Database

Lower Chinle Non-Mixing Zone

The Lower Chinle aquifer subcrops west of the Valle Verde subdivision and of the West Fault and southwest of Broadview Acres between the faults (Figure 19). The aquifer extends east and northeast of the subcrops.

HMC based the background determination for Lower Chinle nonmixing zone on data from 1995 through July 2002. HMC recommended background equal to 0.03 mg/l, with the 95% exceedance equaling 0.02 mg/l (HMC 2015) (Figure 20). Prior to 1995, a few observations slightly exceeded 0.03 mg/l at WCW. Beginning in July 2002, a significant increase commenced with the U concentration in CW29 almost reaching 0.2 mg/l. The mixing zone primarily has concentrations less than 0.03 mg/l, but in well CW43 the concentrations have increased to exceed 0.04 mg/l. Well CW43 is nearest the subcrop over which U concentrations have begun to increase west of the LTP in the paleochannel. Wells CW29 and CW41 are southwest of Felice Acres. Because there are no monitoring wells in the mixing zone south of the wells, it is not possible to track the potential movement of U to these wells from the subcrop. The contamination could result from movement through the East or Middle Faults.

HMC's recommended 0.03 mg/l background is appropriate for the Lower Chinle nonmixing zone.

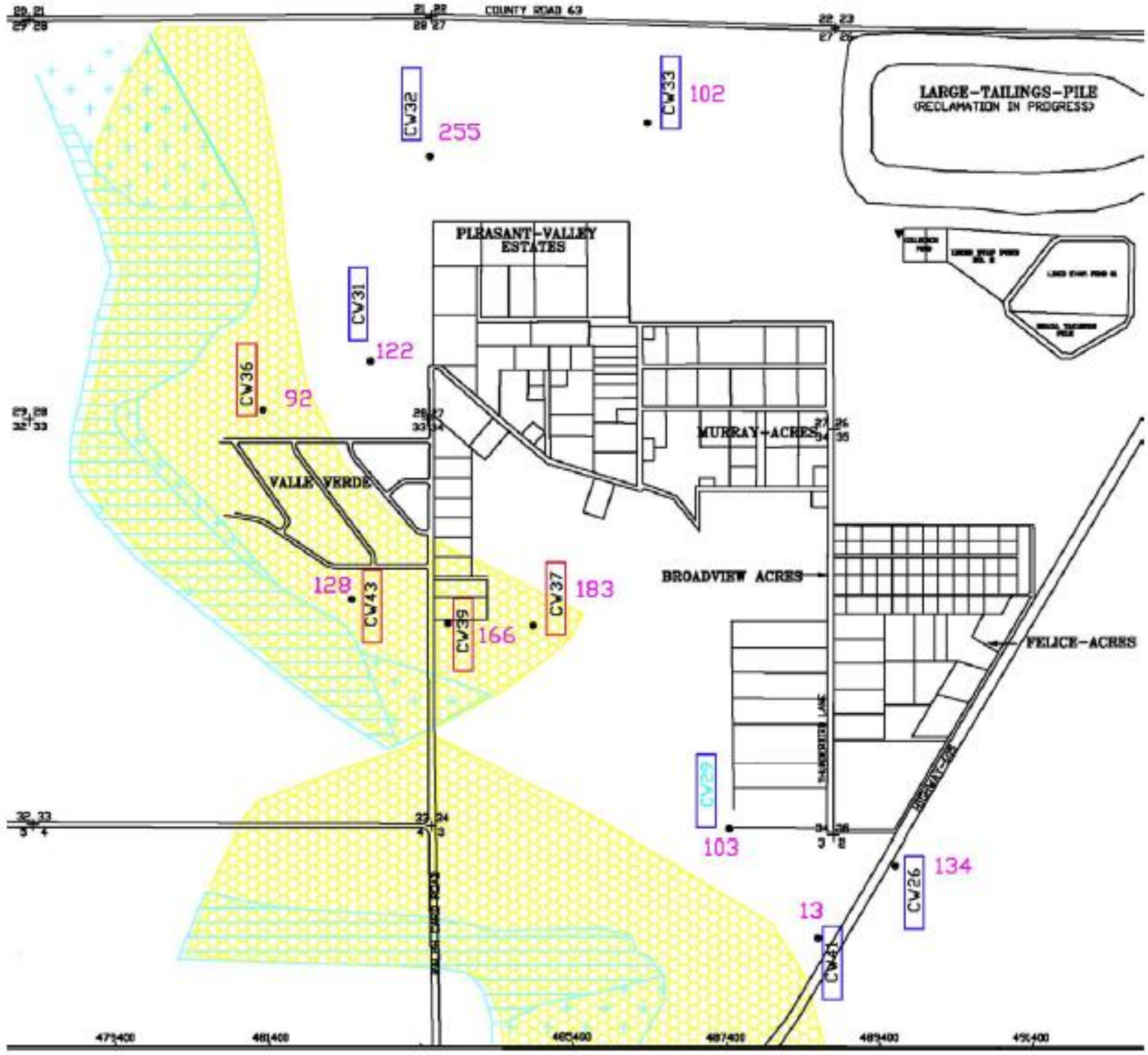

Figure 6-3. Calcium Concentration Comparisons of the Lower Chinle Aquifer in mg/l

Figure 19: Monitoring wells, calcium concentrations, and mixing zone delineation in the Lower Chinle aquifer. Source: HMC (2015) Figure 6-3

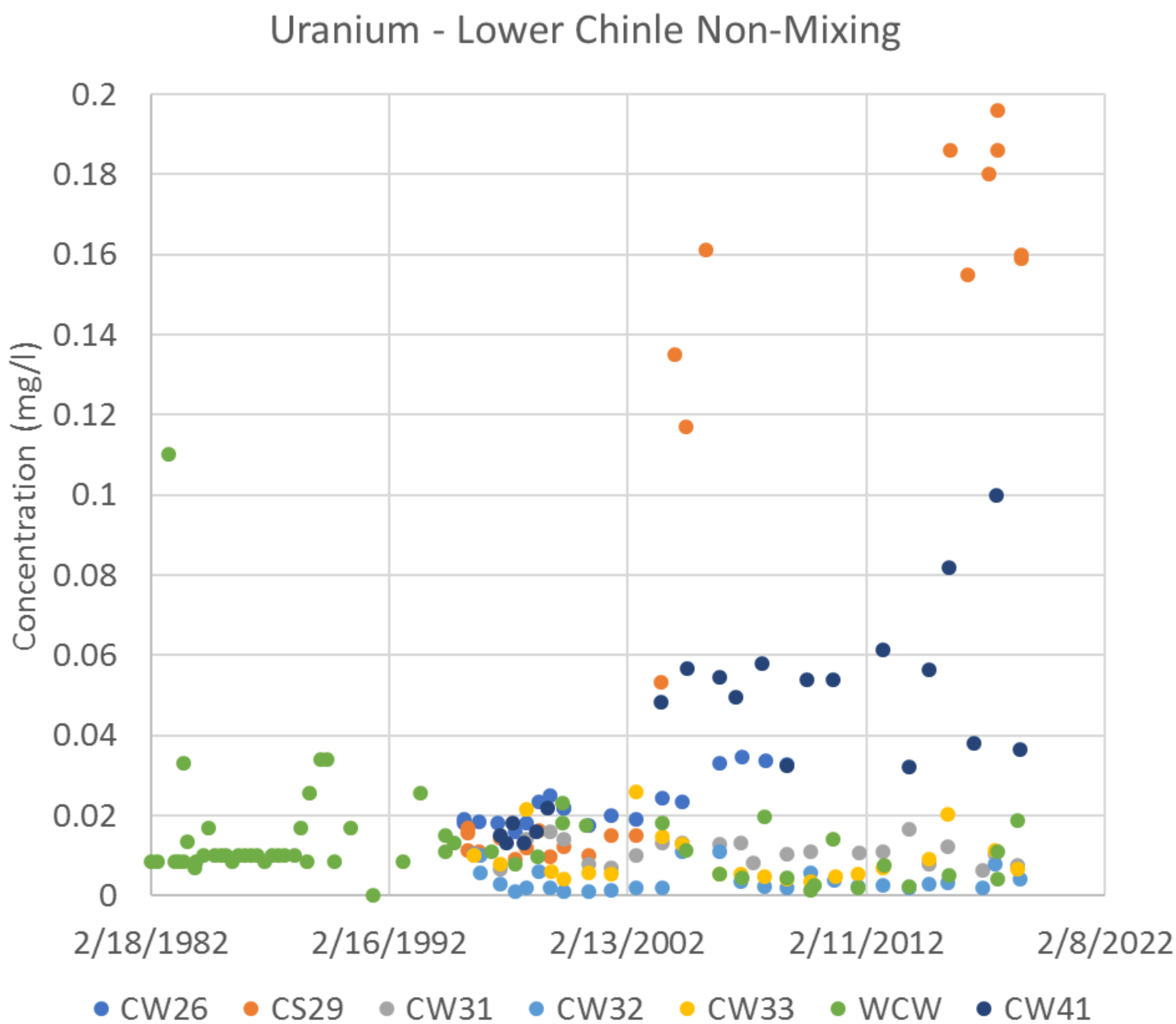

Figure 20: Uranium concentrations for the Lower Chinle non-mixing zone wells. Source of data: Homestake digital groundwater chemistry database

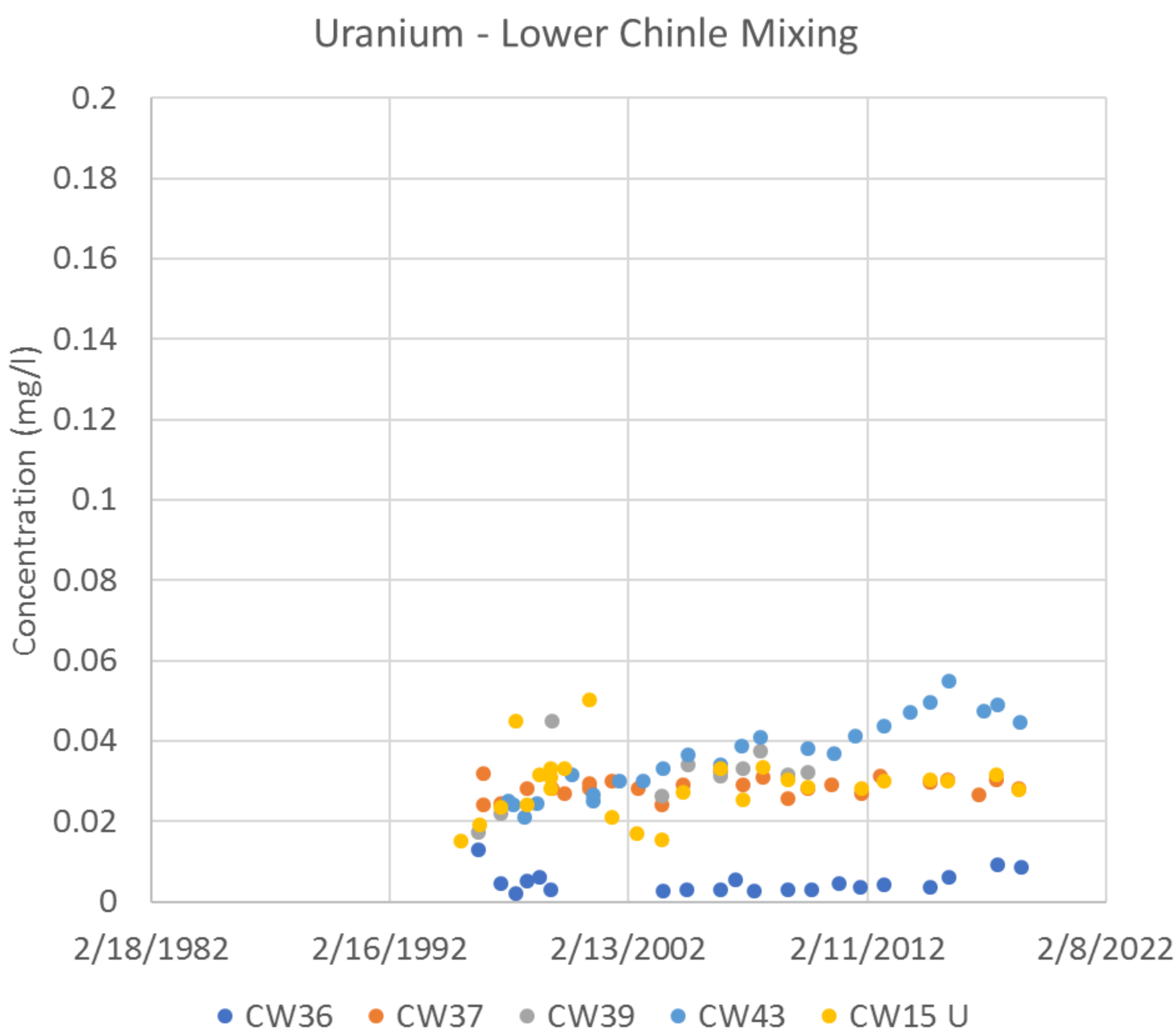

Figure 21: Uranium concentrations for the Lower Chinle mixing zone wells. Source of data: Homestake digital groundwater chemistry database

Chinle Mixing Zones

HMC determined the mixing zones based on calcium concentrations, as noted above, and generally were downgradient from the subcrops. Figures 13, 16, and 21 show the U concentration trends for these areas. HMC combined the mixing zones for the three Chinle layers, although there are large differences in the data among the layers. They estimate background using 4, 5, and 4 wells for the Upper, Middle and Lower Chinle, respectively, with data from 1988 to 2003, although only the Upper Chinle has data prior to 1995. HMC estimated background equal to 0.18 mg/l.

For the upper Chinle mixing zone, different wells are presented at different times rendering it difficult to determine trends (Figure 13). Overall, concentrations are generally less than 0.06 mg/l with the two wells that have data prior to 1990 being less than 0.04 mg/l. No trends are apparent except that data collected later in the period are higher than those collected earlier, but from different wells. Middle Chinle concentrations substantially exceeded 0.05 mg/l with three exceeding 0.10 mg/l at four of the five wells which also range to almost 0.2 mg/l with no trend from 1992 (Figure 16). The four wells with high concentrations are just west of the LTP near the West Fault (which now may be considered closer to the LTP than it was previously) in the high U flow path (Figure 4). The fault has been considered a pathway to the Chinle and the data confirm that hypothesis. Concentrations for the lower Chinle tend to be less than 0.04 mg/l, with some upward trend starting about 2003 (after the background period and possibly due to flushing at the LTP (HMC 2019)) at CW43 to greater than 0.05 mg/l; this could easily be linked to the earlier high U concentrations in the alluvium near the lower Chinle subcrop.

As described, HMC grossly overestimated the background concentrations for the Chinle mixing zones because it included impacted Middle Chinle mixing zone wells. Most U concentrations in the Upper and Lower Chinle mixing zones are less than 0.05 mg/l, the high values in the Middle Chinle mixing zone controls HMC's estimated background. All HMC data from the Upper and Lower Chinle mixing zone and Middle Chinle well CW15 through 2018 are appropriate to consider for background. Extending the data through the present for unaffected wells is appropriate due to the lack of trends. The 95% exceedance is 0.048 mg/l, with the median being 0.0275 mg/l (Figure 22). A fair background level for the Chinle mixing zones is 0.05 mg/l, not the 0.18 mg/l as proposed by HMC. The primary difference is to not consider the Middle Chinle mixing zone wells under the high-U pathway west of the LTP. It is appropriate that the mixing zone has a higher background than the alluvium because it is possible the water attains some U passing into the Chinle.

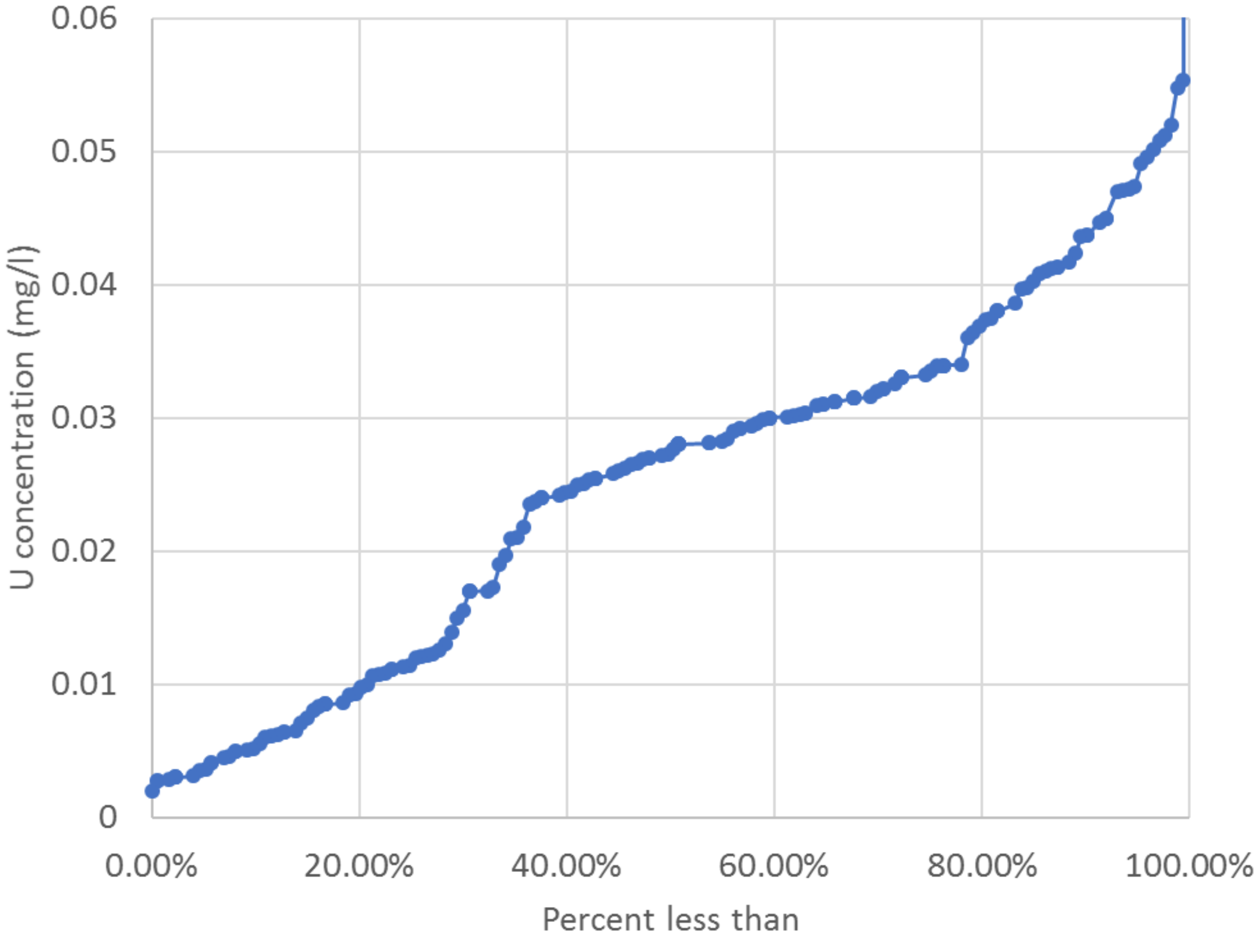

Figure 22: Percent exceedance plot for Chinle mixing zone wells not affected by millsite contamination, from 1987 through 2018. Includes wells CW9, CW10, CW50, CS52, CW36, CW37, CW39, and CW15. One observation is off the chart at 0.3 mg/l. Data source: HMC database

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